E. **Wigner**, ***The Limits of Science***.
Proc. Amer. Phil. Soc., **94**, 422 (1950).

60 years ago !

The time of life of one generation !

ISHEPP2010/Dubna, October 4-9

Finite Formation Time of Hadrons and QGP Production: TO BE OR NOT TO BE?

Sergey M. Eliseev

Bogoliubov Laboratory of Theoretical Physics,
Joint Institute for Nuclear Research,
141980 Dubna, Russia

Prof. R. Hagedorn outlined the genuine situation with the investigation of QGP and highlighted the current problem:

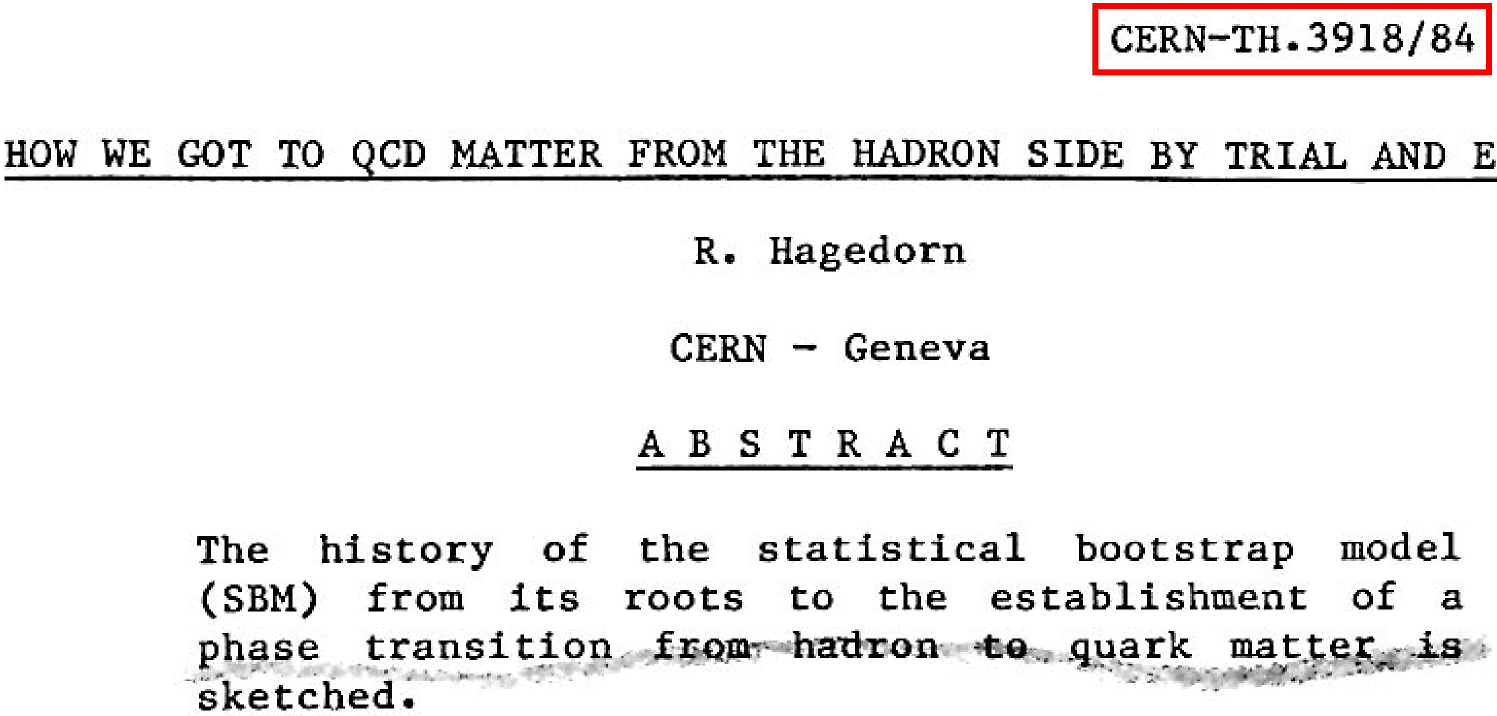
"If you ask me now why it took 27 years to arrive at the present (still problematic) state, (QM), let me answer with Shakespear:

There are more things in Heaven and Earth, Horatio, than are dreamt of in your philosophy."

W. Shakespear, Hamlet (1601).

See:

R. Hagedorn, ***"How we got to QCD matter from hadron side by trial and error"***, QM 1984, June 17-21, 1984,Helsinki.



CERN-TH.3918/84

HOW WE GOT TO QCD MATTER FROM THE HADRON SIDE BY TRIAL AND ERROR*)

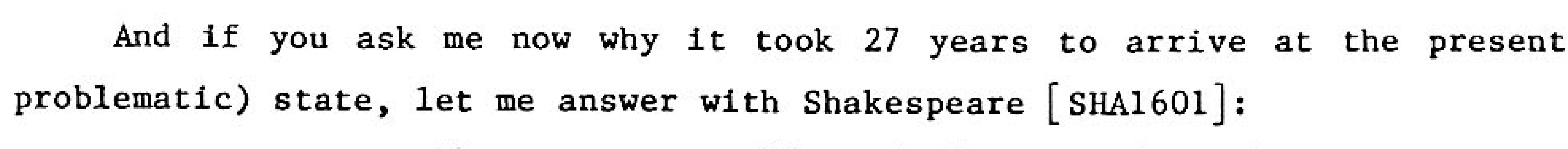
R. Hagedorn

CERN - Geneva

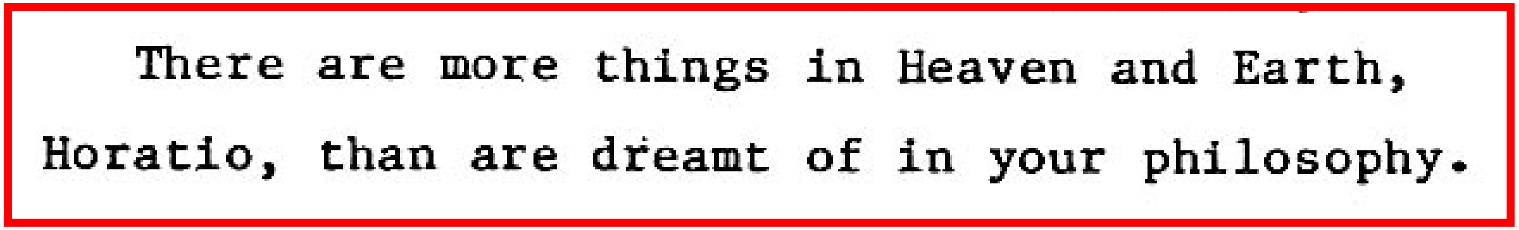
ABSTRACT

The history of the statistical bootstrap model (SBM) from its roots to the establishment of a phase transition from hadron to quark matter is sketched.

Last page of this Preprint → - 19 -



And if you ask me now why it took 27 years to arrive at the present problematic) state, let me answer with Shakespeare [SHA1601]:



> There are more things in Heaven and Earth,
> Horatio, than are dreamt of in your philosophy.

Historically, the instability of the hadron phase was first argued by Hagedorn before the discovery of QCD. He pointed out the possibility of a phase transition at finite temperature, based on the string or the flux-tube picture of hadrons. After QCD was established as the fundamental theory of the strong interaction, this transition was recognized as the deconfinement phase transition to the QGP phase, where quarks and gluons are liberated with the **restored chiral symmetry**.

F. Cerulus and R. Hagedorn, Supp. Nuovo Cimento **9**, 646 (1958).

R. Hagedorn, Nuovo Cimento **56A**, 1027 (1968)

53 years → It is more than time of active life of one generation.

VOLUME 6, NUMBER 11 PHYSICAL REVIEW LETTERS JUNE 1, 1961

EVIDENCE FOR A π-π RESONANCE IN THE $I=1$, $J=1$ STATE*

A. R. Erwin, R. March, W. D. Walker, and E. West
Brookhaven National Laboratory, Upton, New York and University of Wisconsin, Madison, Wisconsin

(Received May 11, 1961)

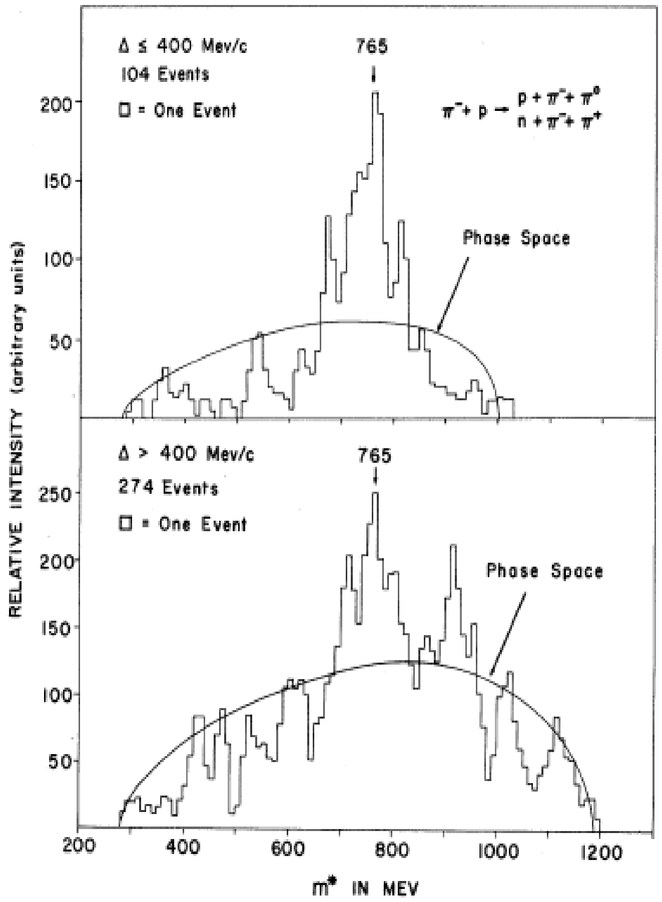


FIG. 2. The combined mass spectrum for the $\pi^-\pi^0$ and $\pi^-\pi^+$ system. The smooth curve is phase space as modified for the included momentum transfer and normalized to the number of events plotted. Events used in the upper distribution are not contained in the lower distribution.

Volume 6, Number 11 PHYSICAL REVIEW LETTERS June 1, 1961

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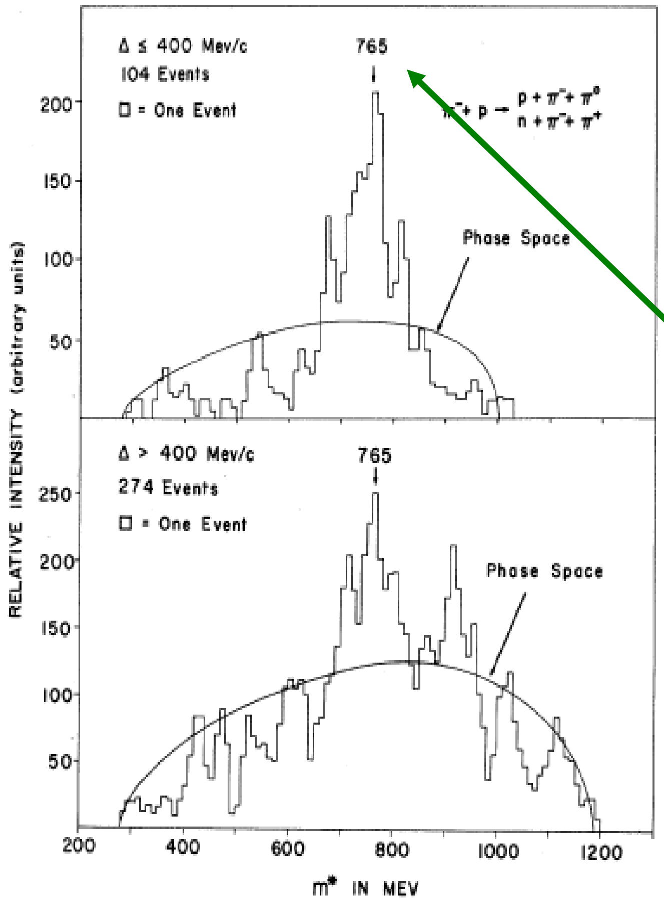
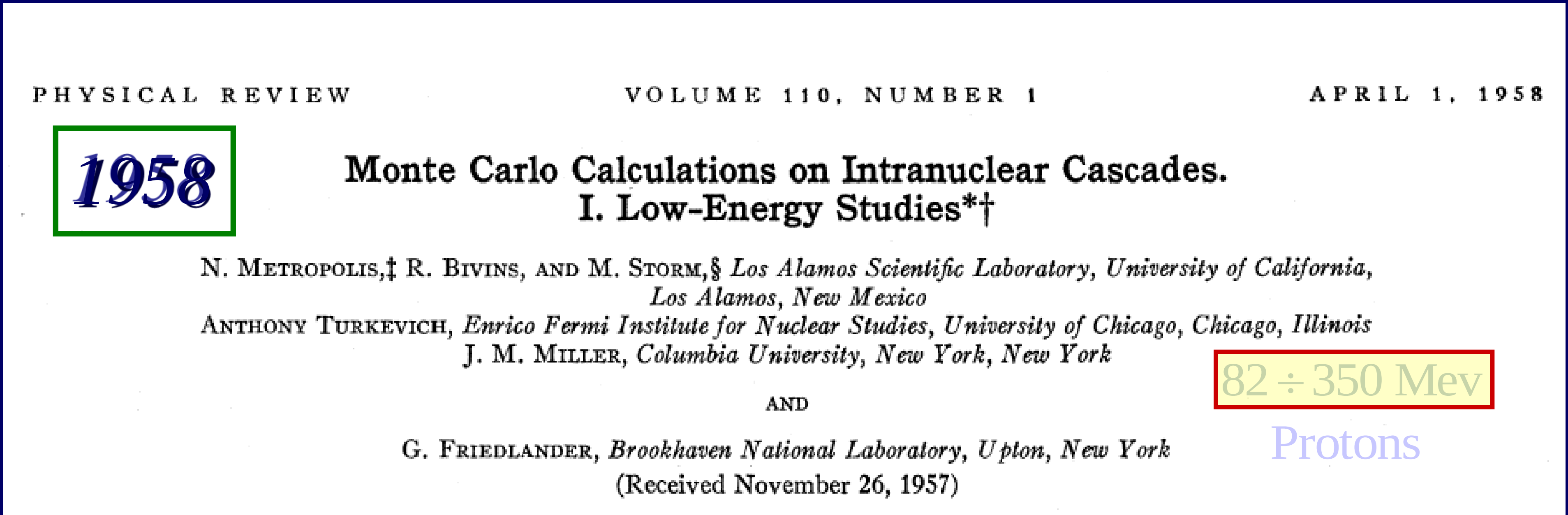


FIG. 2. The combined mass spectrum for the $\pi^-\pi^0$ and $\pi^-\pi^+$ system. The smooth curve is phase space as modified for the included momentum transfer and normalized to the number of events plotted. Events used in the upper distribution are not contained in the lower distribution.

$$m_\rho \approx 765 MeV$$



PHYSICAL REVIEW VOLUME 110, NUMBER 1 APRIL 1, 1958

1958

Monte Carlo Calculations on Intranuclear Cascades.
I. Low-Energy Studies*†

N. Metropolis,‡ R. Bivins, and M. Storm,§ *Los Alamos Scientific Laboratory, University of California, Los Alamos, New Mexico*
Anthony Turkevich, *Enrico Fermi Institute for Nuclear Studies, University of Chicago, Chicago, Illinois*
J. M. Miller, *Columbia University, New York, New York*

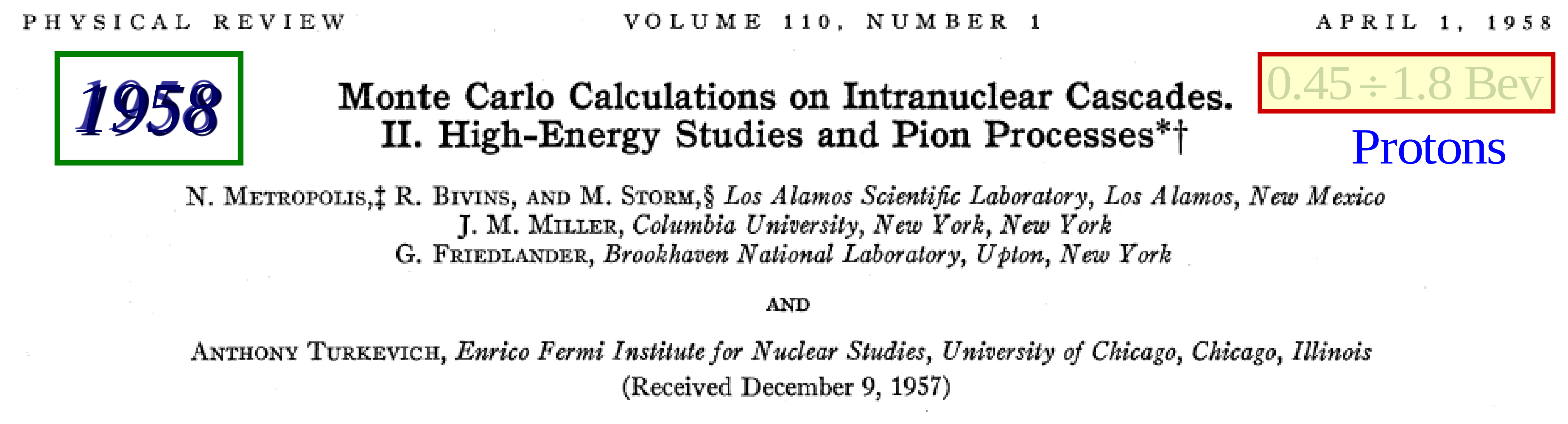
and

G. Friedlander, *Brookhaven National Laboratory, Upton, New York*

82 ÷ 350 Mev

Protons

(Received November 26, 1957)



PHYSICAL REVIEW VOLUME 110, NUMBER 1 APRIL 1, 1958

1958

0.45 ÷ 1.8 Bev

Protons

Monte Carlo Calculations on Intranuclear Cascades.
II. High-Energy Studies and Pion Processes*†

N. Metropolis,‡ R. Bivins, and M. Storm,§ *Los Alamos Scientific Laboratory, Los Alamos, New Mexico*
J. M. Miller, *Columbia University, New York, New York*
G. Friedlander, *Brookhaven National Laboratory, Upton, New York*

and

Anthony Turkevich, *Enrico Fermi Institute for Nuclear Studies, University of Chicago, Chicago, Illinois*

(Received December 9, 1957)

Nuclear Physics 87 (1966) 241—255;©*North-Holland Publishing Co., Amsterdam*

INELASTIC INTERACTIONS OF COSMIC RAY PARTICLES WITH ATOMIC NUCLEI AT VERY HIGH ENERGIES

I. Z. ARTYKOV, V. S. BARASHENKOV and **S. M. ELISEEV**
Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna

Received 18 February 1966

Abstract

The nucleon-nucleus interactions in the energy range **T = 100 -1000 GeV** are analysed from the point of view of the mechanism of intranuclear cascades in its generally accepted form (as a series of independent two-particle interactions). .. The result… the cascade calculation **is strongly contradictory with the experimental data…etc.**

Nuclear Physics B59 (1973) 128-140 ;©*North-Holland Publishing Co., Amsterdam*

INTERACTIONS OF PIONS WITH HEAVY EMULSION NUCLEI

S.M. ELISEEV and J.M. KOHLI
Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna

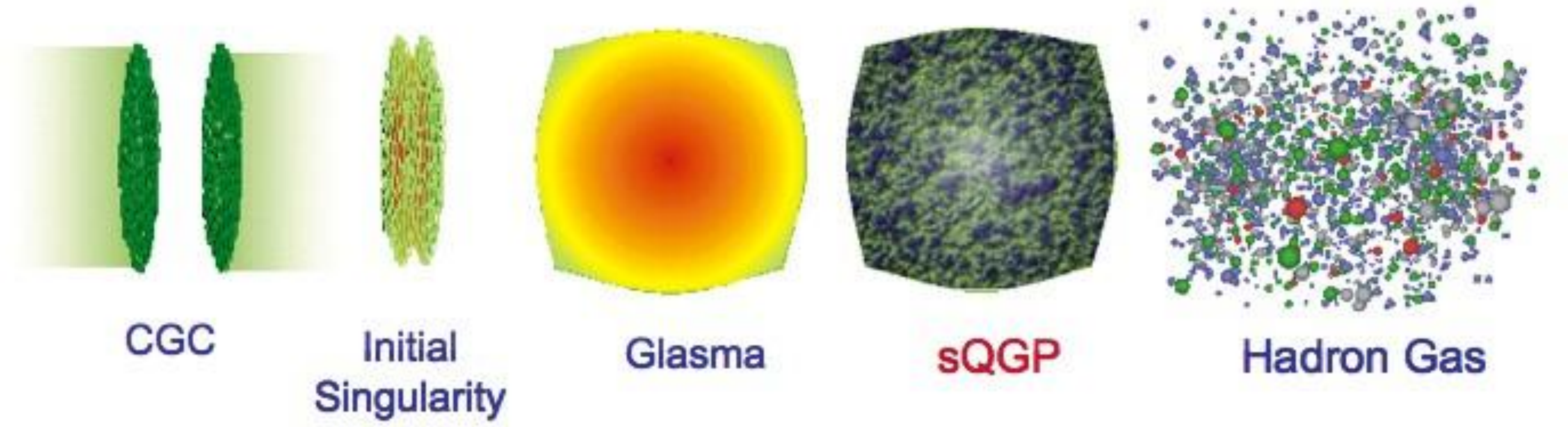
Received 4 October 1972

Abstract

An analysis of the basic characteristics of secondary particles created in the interaction of pions with heavy emulsion nuclei **at the highest accelerator energies available** is presented. Calculations were performed with an intranuclear cascade model using the Monte-Carlo method, taking into account the "trailing effect". The theoretical results were compared with experimental results at 17.2 and 60 GeV interactions.

Raju Venugopalann, *From Glasma to Quark Gluon Plasma in heavy ion collisions* J.Phys.G35:104003,2008

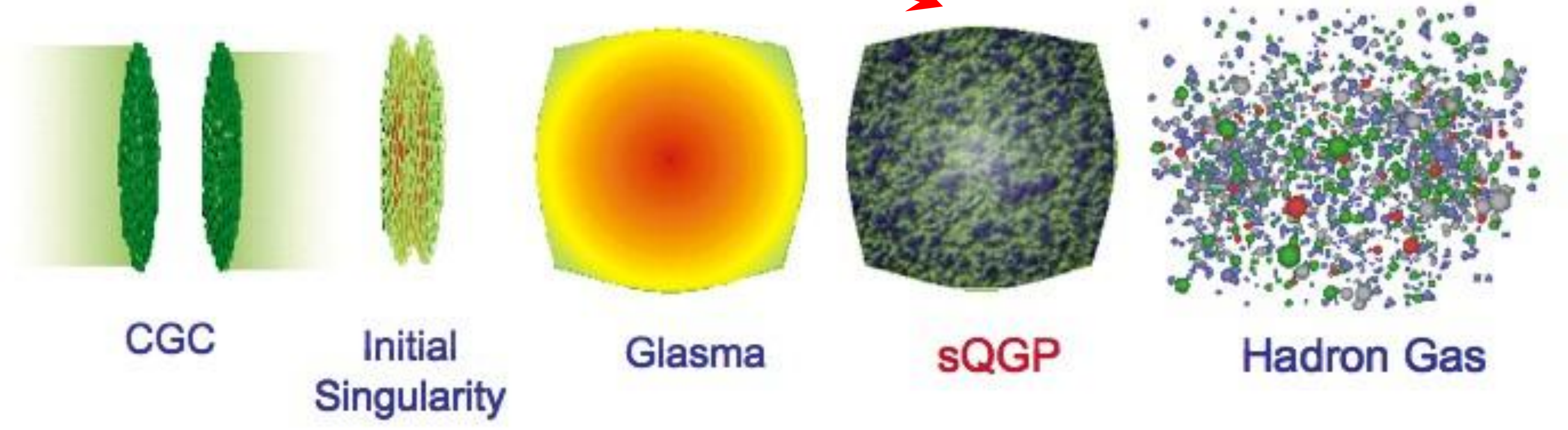
Glasma → the non-equilibrium matter preceding the QGP,



Raju Venugopalann, *From* ***Glasma*** *to Quark Gluon Plasma in heavy ion collisions* J.Phys.G35:104003,2008

Divide a skin of a not killed bear ??

Glasma → the non-equilibrium matter preceding the QGP,



In this Report, I want to draw too much attention to the problem of formation time.

It is necessary to take into account the time needed for the formation of particles produced at high energy.

Why?

Firstly….because of:

In analysis of data on multiparticle production in proton – nucleus interactions at high energy it has turned out that the cascading of secondaries is considerably lower than expected under the assumption that a secondary pion is able to interact **immediatelly** after it has been produced in a nucleon – nucleon collision. And this has been ascribed to the formation time of secondary particles.

In a high energy collision between two hadrons it takes a finite amount of time for the reaction products to evolve to physical particles. The time cannot be calculated within perturbative QCD because the hadronization process involves small Momentum transfers.

In Deep Inelastic Scattering on nuclear targets (nDIS) one observes a suppression of hadron production analogous to hadron quenching in heavy-ion collision at the Relativistic Heavy-Ion Collider (RHIC).
Moreover, the nucleons act as femtometer-scale detectors allowing to experimentally study the propagation of a parton in this ``cold nuclear matter'', and its space-time evolution into the observed hadron. In the case of heavy ion collisions, one wants to use hadron suppression as a tool to extract the properties of the hot and dense system created in the collision, also called ``hot nuclear matter''.

The Leading Role of Formation Time:

From Few-Body:

M.A. Braun, C. Ciofi degli Atti, L.P. Kaptari, H.Morita, “***Finite Formation Time in Electro-Disintegration of Few-Body Nuclei*** ”, arXiv:nucl-th/0308069.

To Heavy Nuclei:

1.) Peter Filip, Jan Pisut,***“Hadron Formation Time and Dilepton Mass Spectra in Heavy Ion Collisions”,*** arXiv:nucl-th/9705051.

2.) Sa Ben-Hao, *et al*., ***“Formation time effect on*** $J\backslash\Psi$ ***Dynamical Nuclear Suppression”,*** arXiv:nucl-th/9803033.

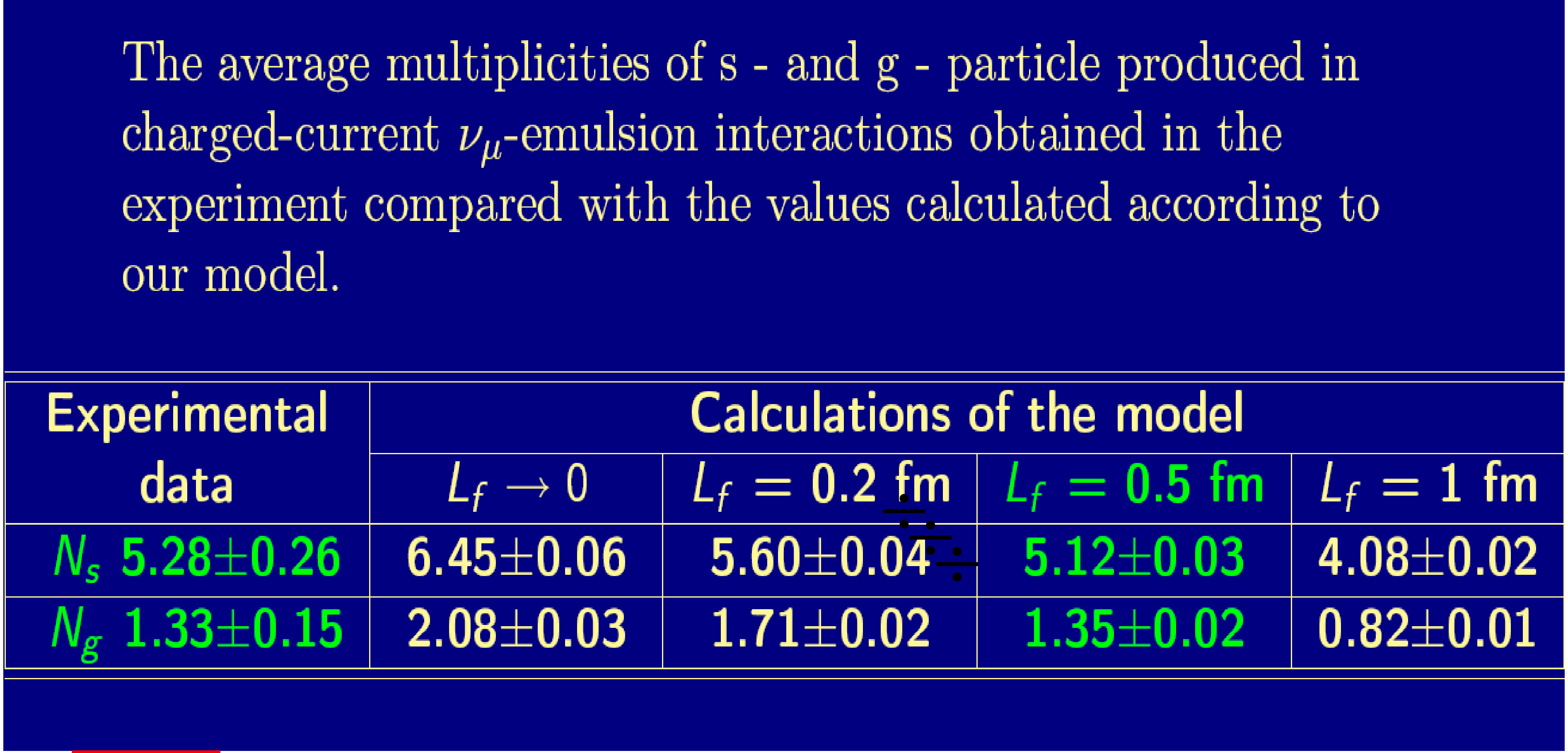
$$\sigma_{hN} = \sigma_{hN}^{exp}(1 - e^{-L/L_f})$$

If $L \rightarrow o$ $\sigma_{hN} \rightarrow 0$

If $L \rightarrow \infty$ $\sigma_{hN} \rightarrow \sigma_{hN}^{exp}$

The present data discussed below have been obtained in the Fermilab experiment. In this experiment, the nuclear emulsion was exposed in the wide-band neutrino beams. The neutrino energy spectrum peaks at about 15 GeV, and extends to about 200 GeV.

The nuclear emulsion → $A \,\square\, 1 \div 108,\ \langle A \rangle \approx 70.$



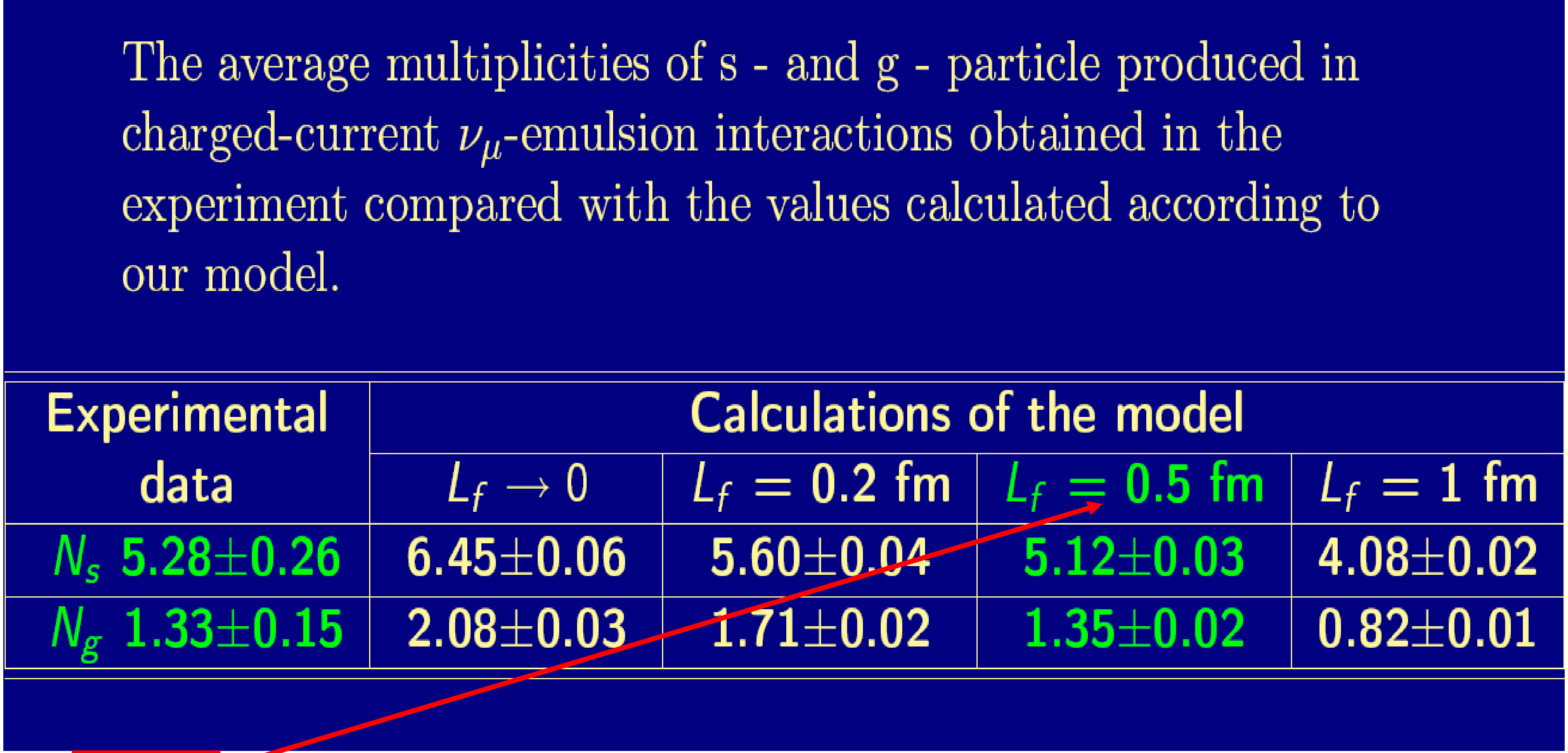
The average multiplicities of s - and g - particle produced in charged-current ν_μ-emulsion interactions obtained in the experiment compared with the values calculated according to our model.

Experimental data	Calculations of the model			
	$L_f \to 0$	$L_f = 0.2$ fm	$L_f = 0.5$ fm	$L_f = 1$ fm
N_s 5.28±0.26	6.45±0.06	5.60±0.04	5.12±0.03	4.08±0.02
N_g 1.33±0.15	2.08±0.03	1.71±0.02	1.35±0.02	0.82±0.01

$\boxed{L_f\ -}$ **formation length <u>(in the system of particle)</u>**

s - particles $\begin{cases} \underline{\text{charged pions}} \quad E_{kin} \geq 60 \ \text{MeV} \\ \underline{\text{protons}}, \quad E_{kin} \geq 400 \end{cases}$

g - particles $\longrightarrow$ <u>protons</u> $E_{kin} = 27 \div 400$ MeV



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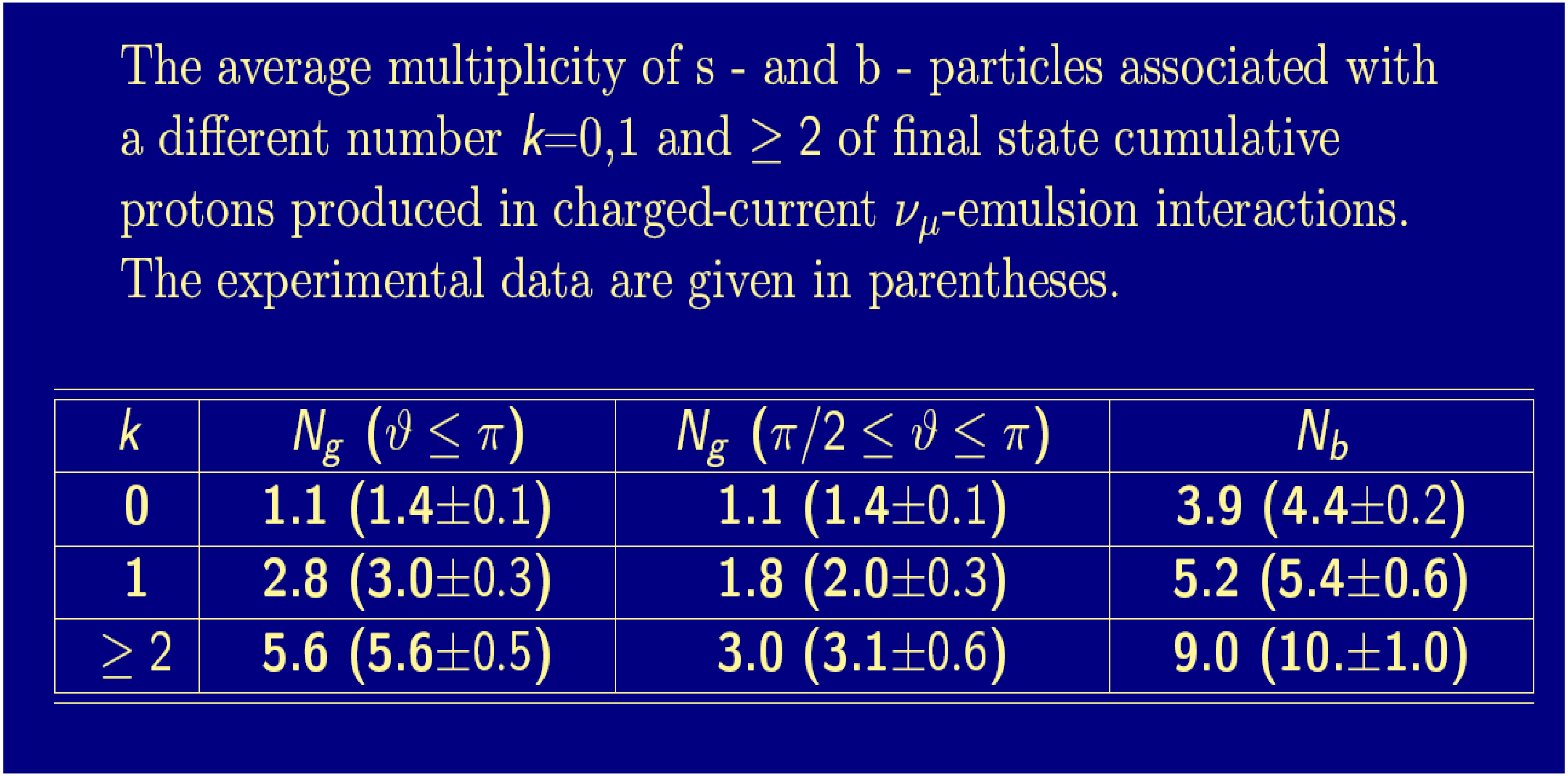
$\boxed{L_f -}$ **formation length (in the system of particle),**

s - particles

$\left\{ \begin{array}{l} \text{charged pions} \quad E_{kin} \geq 60 \text{ MeV} \\ \text{protons,} \quad E_{kin} \geq 400 \end{array} \right.$

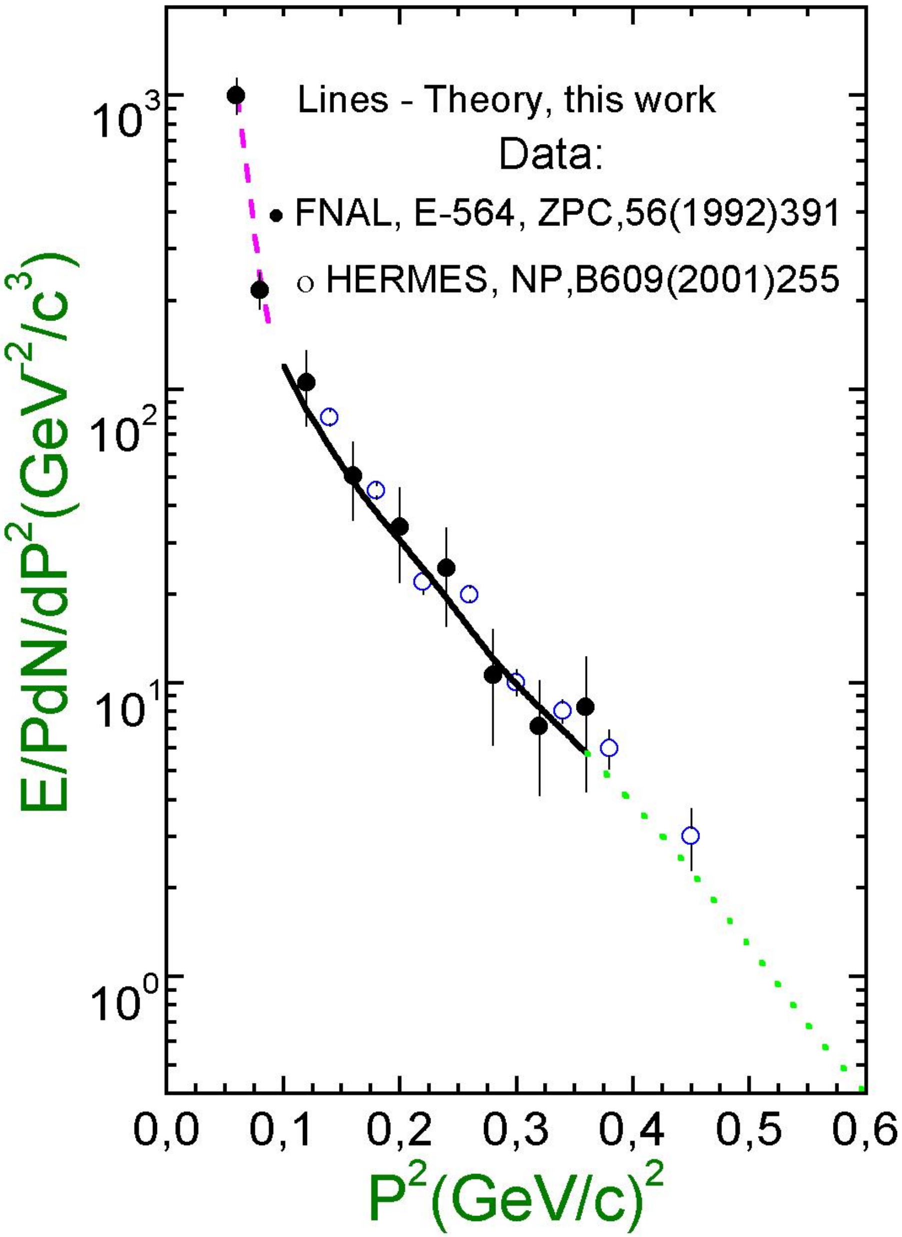
g - particles $\longrightarrow$ protons $E_{kin} = 27 \text{ -- } 400$ MeV



The average multiplicity of s - and b - particles associated with a different number k=0,1 and ≥ 2 of final state cumulative protons produced in charged-current ν_μ-emulsion interactions. The experimental data are given in parentheses.

k	N_g ($\vartheta \leq \pi$)	N_g ($\pi/2 \leq \vartheta \leq \pi$)	N_b
0	1.1 (1.4±0.1)	1.1 (1.4±0.1)	3.9 (4.4±0.2)
1	2.8 (3.0±0.3)	1.8 (2.0±0.3)	5.2 (5.4±0.6)
≥ 2	5.6 (5.6±0.5)	3.0 (3.1±0.6)	9.0 (10.±1.0)

$$\boxed{L_f = 0.5\text{fm}}$$


Lines - Theory, this work
Data:
● FNAL, E-564, ZPC,56(1992)391
○ HERMES, NP,B609(2001)255
10^3
10^2
10^1
10^0
0,0
0,1
0,2
0,3
0,4
0,5
0,6
$E/PdN/dP^2(GeV^{-2}/c^3)$
$P^2(GeV/c)^2$

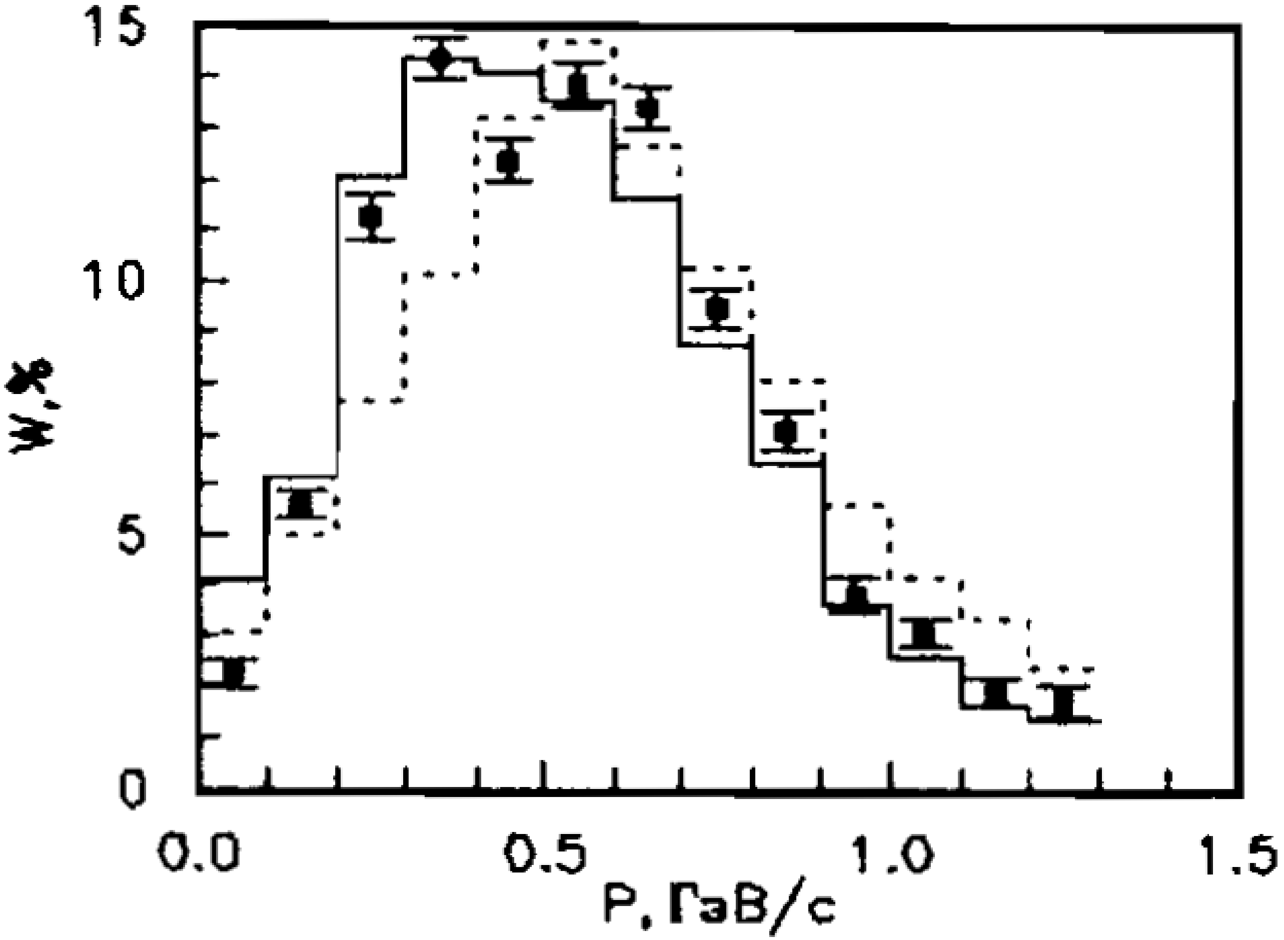
Interaction of a primary particle with nucleon of nucleus and creation of faierbol.

Cascades initiated by recoil nucleons at faierbol-nucleon interaction in a nucleus.

s - particles → $\beta > 0.7 \begin{cases} \text{\underline{charged pions}} & E_{kin} \geq 60 \ \text{MeV} \\ \text{\underline{protons},} & E_{kin} \geq 400 \end{cases}$

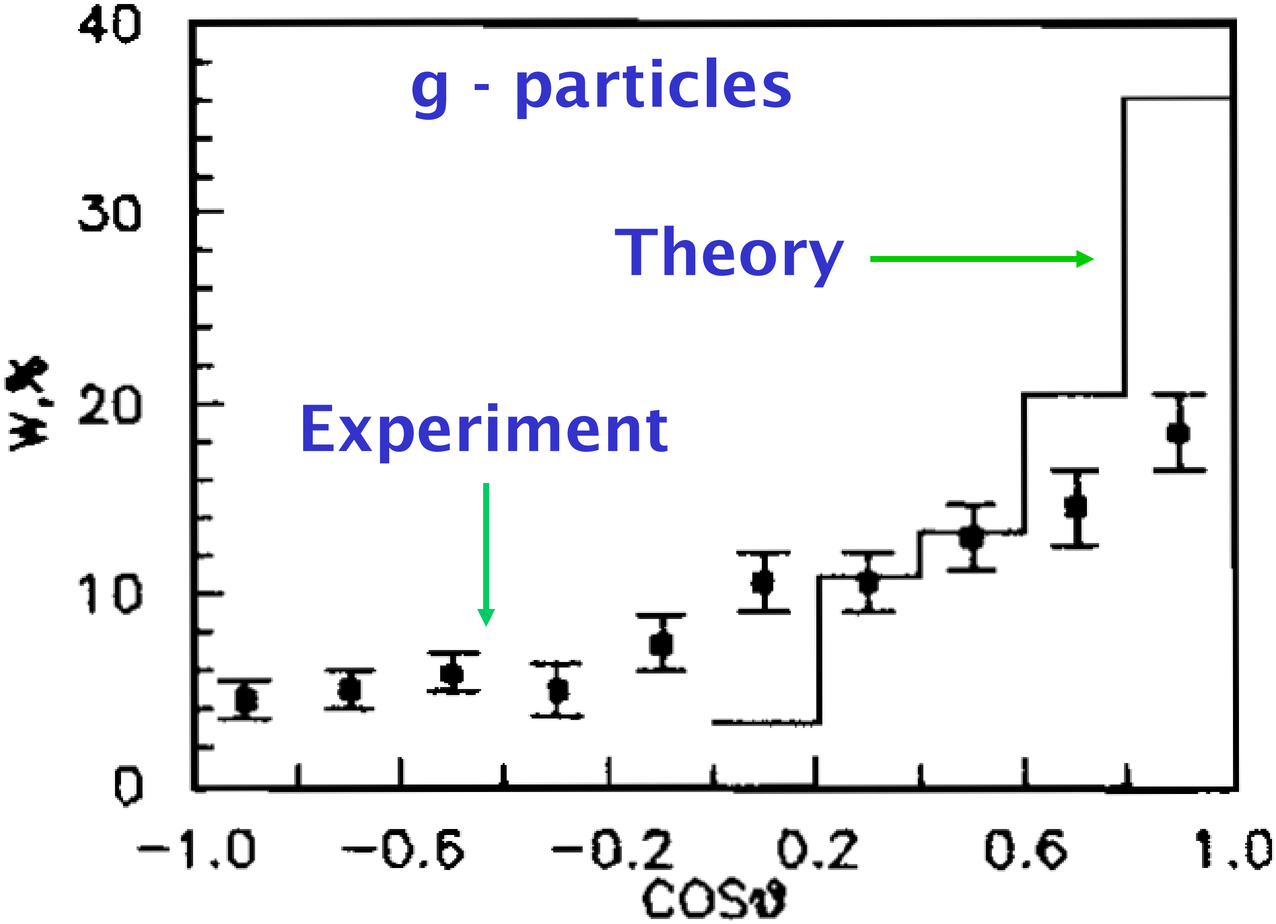
g - particles → <u>protons</u>, $E_{kin} = 27 \div 400$ MeV

b - particles → low energy particles emitted mainly due to evaporation.



...... nucleons from klaster + N interaction in nucleus

—— nucleons from p+Em interaction (g – particles)



P + nuclear emulsion (Em), E=200 GeV

Em (A □ 1 ÷ 108), $\langle A \rangle \approx$ 70

Using Glauber approach

Why?

The experimental results on the production of J/Ψ in p-A and A-A collisions are interpreting (as a general rule) in the framework of models without the quark - gluon plasma.

See:

Kaidalov A.B. *et al.*, :”*A conventional hadronic framework based on Glauber nuclear absorption plus final state interaction:* J/Ψ *and* $\pi 0$ *production in nuclear collision*”.

From: Phys.Lett. **B206,** 354 (1988) **till now**.

And:

“*Anomalous suppression of* J/Ψ *and* π^0 *production at large transverse momentum in Au + Au and d + Au collisions* at = 200 GeV”

An abnormal suppression of *J* / Y was observed in some experiments On high energy nuclear collisions. That suppression (at once) was interpreted as a hint for the formation of a quark - gluon plasma. However, the experimental results on the production of *J* / Y in p-A and A-A collisions are interpreting (as a general rule) in the framework of models without the quark - gluon plasma. That models are based on the using of customary ingredients: the Glauber approximation, zone formation effect, Fermi motion and all that.

A new model *a la* Glauber for hadron - nuclei interaction at intermediate energy is proposed. The main theoretical assumptions such as in the approaches of others authors **describing J/Psi suppression in nuclear collisions** and color transparency of nuclei at high energy are used. Yet, a number of new ingredients in the model: noneikonal corrections, correlations of nucleons in the nuclei is introduced. The nuclear Fermi motion effect was taken into account. The momenta of the intranuclear nucleons are sampled using Monte Carlo method.

$$f(q) = \frac{ik}{2\pi}\int e^{i\vec{q}.\vec{b}}[1 - e^{i\chi(\vec{b})}]d\vec{b},$$

B.M. Barbashov, S.P. Kuleshov, V.A. Matveev, V.N. Pervushin, A.N. Sissakian, A.N. Tavkhelidze (Dubna, JINR):
“Straight-line paths approximation for studying high-energy elastic and inelastic hadron collisions in quantum field theory”
Phys.Lett. **B33,** 484 (1970).

$$\Gamma(\vec{b}) \equiv 1 - e^{i\chi(\vec{b})}$$

$$\Gamma(\vec{b}) = \frac{1}{2\pi ik}\int e^{-i\vec{q}\cdot\vec{b}} f(\vec{q})d\vec{b}$$

$$\chi^{(n)}(b) = -\frac{\mu^{n+1}}{k(n+1)!}\left(\frac{b}{k^2}\frac{\partial}{\partial b} - \frac{\partial}{\partial k}\frac{1}{k}\right)^n \int_{-\infty}^{\infty} V^{n+1}(r)dz$$

The nuclear phase shift for a particular configuration of an ensamble of nucleons inside a nucleus is just the sum of the individual phase shifts:

$$\chi_N(\vec{b},\vec{r}_1,\ldots,\vec{r}_A) = \sum_{j=1}^{A} \chi_j(\vec{b}-\vec{s}_j),$$

$$\Gamma_j(b) = (1 - e^{i\chi_j(b)})$$

$$\Gamma_N(\overrightarrow{b},\overrightarrow{r}_1,\ldots,\overrightarrow{r}_A) = (1 - e^{i\chi_N(\overrightarrow{b},\overrightarrow{r}_1,\ldots,\overrightarrow{r}_A)})$$

$$F_{fi}(\overrightarrow{Q}) = \frac{ik}{2\pi}\int e^{i(\vec{q}\cdot\vec{b})} d\vec{b} \langle f \,|\, \Gamma_N(\vec{b},\vec{r}_1,\ldots\vec{r}_A) \,|\, i\rangle$$

$$\boxed{\begin{gathered}\chi(b) = \chi_0(b) + \chi_{NE}(b), \quad \chi_0(b) = \\ \frac{2\pi}{k}\int\limits_{-\infty}^{\infty} f(0)\rho(r)dz = -\frac{\mu}{k}\int\limits_{-\infty}^{\infty} V(r)dz,\end{gathered}}$$

$$\sigma_T = 2\int\limits_0^{\infty}\{1 - \Re\exp[i\chi(b)]\}d\vec{b},$$

$$\sigma_R = \int\limits_0^{\infty}\{1 - |\exp[i\chi(b)]|^2\}d\vec{b}.$$

R.J. Glauber, ”*Cross Section in Deuterium at High Energies*”, Phys.Rev., **100**, 242 (1955).

1925
Nobel Prize, 2005

$$\sigma_d = \sigma_p + \sigma_n + \delta\sigma$$

$$\delta\sigma = -\frac{1}{4\pi}\sigma_p\sigma_n\langle r^{-2}\rangle_d$$

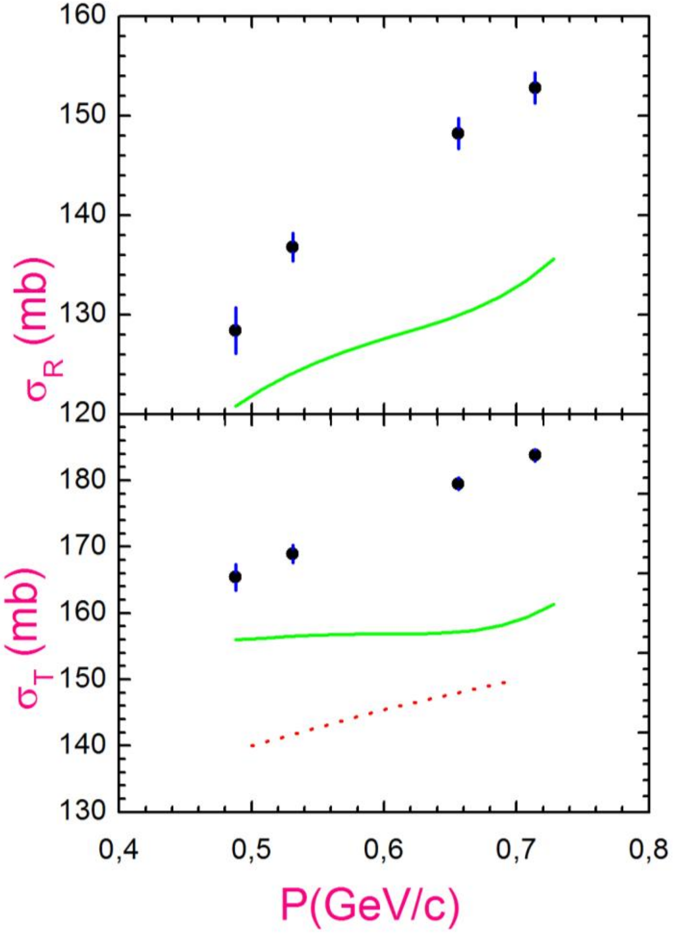
The calculated and experimental total σ_T and reaction σ_R cross sections for K - meson interaction with carbon nucleus *vs.* kaon momentum. The solid lines denote the prediction of our model. The experimental data are from A.Gal, Nucl. Phys., **A 639**, 485c (1998).

The dotted lines demonstrate the theoretical results of

M.F. Jiang *et al.,* Phys. Rev. C **51**, 857 (1995):

"…using a relativistic momentum-space ***optical potential model…***

The theoretical results are found to be below all existing data".



The calculated and experimental total σ_T and reaction σ_R cross sections for K - meson interaction with calcium nucleus *vs.* kaon momentum. The solid lines denote the prediction of our model. The experimental data are from A.Gal, Nucl. Phys., **A 639**, 485c (1998).

The dotted lines demonstrate the theoretical results of
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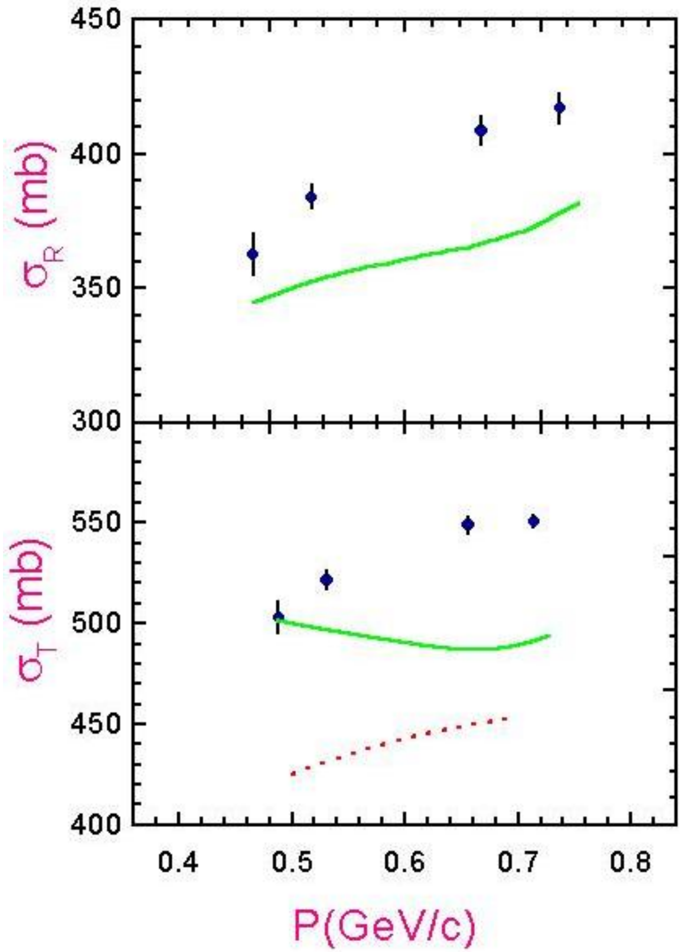
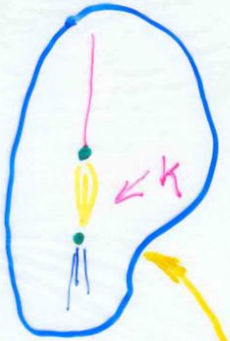


Bridging Low and High Energy Processes: from Nadron-Nuclei to Relativistic Ions collision.

ВЕРОЯТНОСТИ МНОГОЧАСТИЧНЫХ ПРОЦЕССОВ.



ПС

40 ГэВ/с

ЛВЭ, ОИЯИ

②

K	%
2	3.3
3	3.3
4	2.4
5	1
6	0.5
7	0.2
8	0.1
9	0.05

$W_{N \geq 3} \sim 7.7\%$

Outstanding dates conected with our conf.:

A) 60 years after publication of historical work

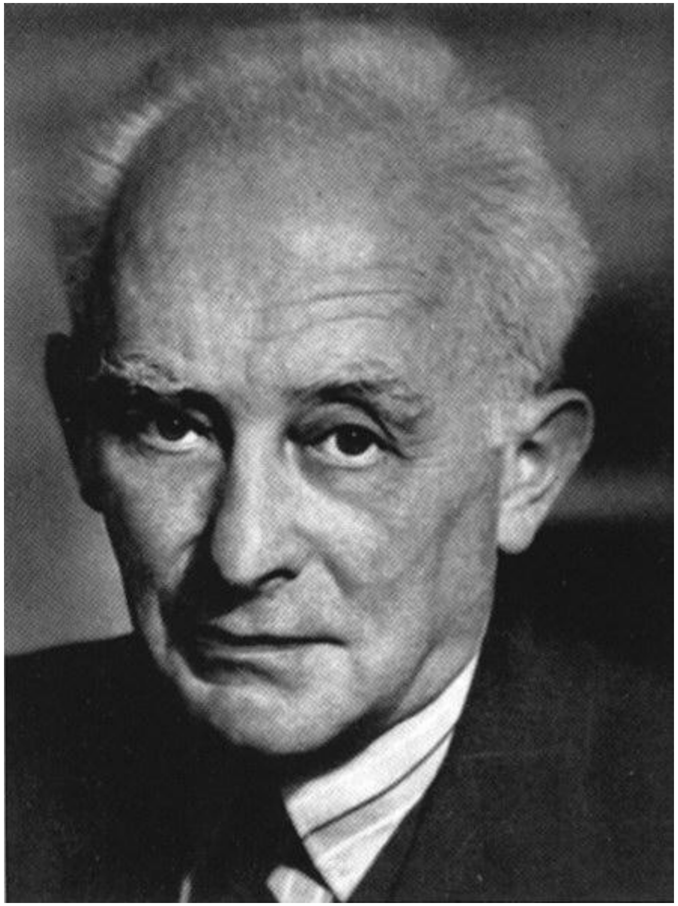
E. **Wigner**, The Limits of Science.
Proc. Amer. Phil. Soc., **94**, 422 (1950).

B) 53 years from the date of the beginning of researches the plasma problem.

C) 61 years from birthday of Prof. V.V. Burov (last but not least, see prev. session).

Я верю, что быстрая смена основных понятий точной науки и неудачи попыток улучшить моральные нормы человеческого общества еще не доказывают тщетность поисков научной истины и лучшей жизни.

I believe that fast change of the basic concepts of our science, and failures of attempts to improve moral standards of a human society yet don't prove futility of searches by a science of true and the best life.



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